A Distributed, Collaborative, Structuring Model for a Clinical-Guideline Digital-Library

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Abstract

The Digital Electronic Guideline Library *(*DeGeL*) is a Web-based framework and a set of distributed tools that facilitate gradual conversion of clinical guidelines from free text, through semi-structured text, to a fully structured, executable representation. Thus, guidelines exist in a* hybrid*, multiple-format representation The three formats support increasingly sophisticated computational tasks. The tools perform semantic markup, classification, search, and browsing, and support computational modules that we are developing, for run-time application and retrospective quality assessment. We describe the DeGeL architecture and its collaborative-authoring authorization model, which is based on (1) multiple medical-specialty* authoring groups*, each including a* group manager *who controls group authorizations, and (2) a* hierarchical authorization *model based on the different functions involved in the hybrid guideline-specification process. We have implemented the core modules of the DeGeL architecture and demonstrated distributed markup and retrieval using the knowledge roles of two guidelines ontologies (Asbru and GEM). We are currently evaluating several of the DeGeL tools.*

Introduction: The clinical-guideline conversion problem

Clinical guidelines have been shown to improve the quality of medical care[1], and are expected to assist in containment of its costs as well. Thus, automated support to runtime guideline application and to retrospective quality assessment would be potentially highly beneficial. Indeed, multiple clinical-guideline ontologies had been designed, and several different computational frameworks proposed, to support guideline-based care in automated fashion[2-11]. Most clinical guidelines, however, are based in free text and are either inaccessible at the point of care, not machine-comprehensible, or both. Thus, the question is how to structure the large set of existing free-text clinical guidelines to support effective search, retrieval, and browsing, as well as application and quality assessment. The core of the guideline-conversion problem is that (1) expert physicians cannot (and do not need to) program in a guideline-specification language, while knowledge engineers do not necessarily understand the clinical semantics of the guidelines; (2) text-based representations are useful for search and retrieval, while formal representations are essential for automated execution.

Our approach to the conversion problem is an *incremental-transformation* one, which involves designing (1) tools that enable expert physicians to *mark-up* (semi-structure) free-text guidelines into a semi-structured representation, using the *knowledge roles* of a chosen clinical-guideline *target ontology* (e.g., *eligibility conditions*), and (2) tools that enable knowledge engineers to convert semi-structured guidelines into a fully structured, machine-comprehensible, executable representation in the target ontology. The three formats support increasingly sophisticated computational tasks (from full-text search, through context-sensitive search and visualization, to automated application and quality assessment), while providing value (e.g. enhanced retrieval precision, by using context-sensitive search) at each conversion phase. The classification, mark-up, search, and browsing tools are independent of the target ontology; the machine-comprehensible representations are ontology-specific.

The DeGeL hybrid-representation model

To gradually convert a large mass of free-text clinical guidelines to a set of target ontologies, we have developed a Web-based, distributed architecture, the **Digital electronic Guideline Library**, (**DeGeL**)[12], and several web-based tools, which gravitate a guideline gracefully from text-based, through structured text (labeled by the knowledge roles of a target ontology), to a fully formal, machine- readable, executable representation (Figure 1).

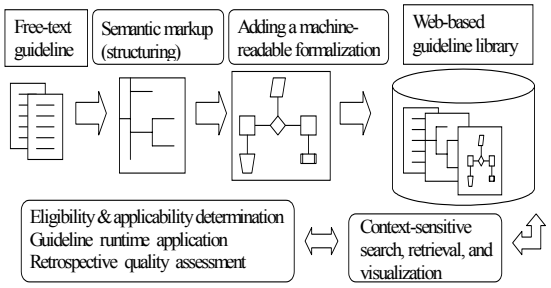

Figure 1. The hybrid meta-ontology and incremental-conversion process in the **DeGeL** architecture. Input free-text guidelines are uploaded from various sources and loaded into a markup editor, in which expert physicians classify and structure the free-text guidelines using the knowledge roles of target guideline ontology. Knowledge engineers add executable expressions by filling additional levels in the target-ontology's representation.

The *meta-ontology* of the DeGeL library is a **hybrid** one, in the sense that it is possible to represent each guideline using one or more representations: free-text, semi-structured text, and fully structured, machine-comprehensible text[12]. It is even possible to represent different knowledge roles in the guideline using different specification formats (e.g., having fully structured eligibility conditions supports automated eligibility determination). *Expert physicians* classify and markup free-text guidelines, by labeling portions of the text using the selected machine-executable representation of the target ontology, using an ontology-dedicated tool. (Both representation formats use XML). Our current default guideline ontology is the expressive Asbru language, developed as part of the Asgaard project[6], which has the advantage of explicitly representing process and outcome *intentions* of guideline designers, thus supporting automated quality assessment[13]. We also experimented with the GEM ontology [11], although, unlike Asbru, it is mainly an intermediate representation without a full computational model.

The DeGeL authoring-support tools

The DeGeL library includes several Web-based, ontology-independent, authoring tools[12].

Uruz is the DeGeL library's Web-based clinical-guideline *markup* tool (Figure 2). A *source guideline* is uploaded into the DeGeL library, and can then be used by Uruz to create a new *guideline document,* marked-up by the semantic labels of one of the target ontologies available in DeGeL. Uruz can also be used to create a guideline document *de-novo* (i.e., without using any source) by directly writing into the knowledge roles of the selected target ontology. We are developing an Asbru-dedicated tool to add the formal-specification level, which is specific to the Asbru procedural semantics, and its temporal model.

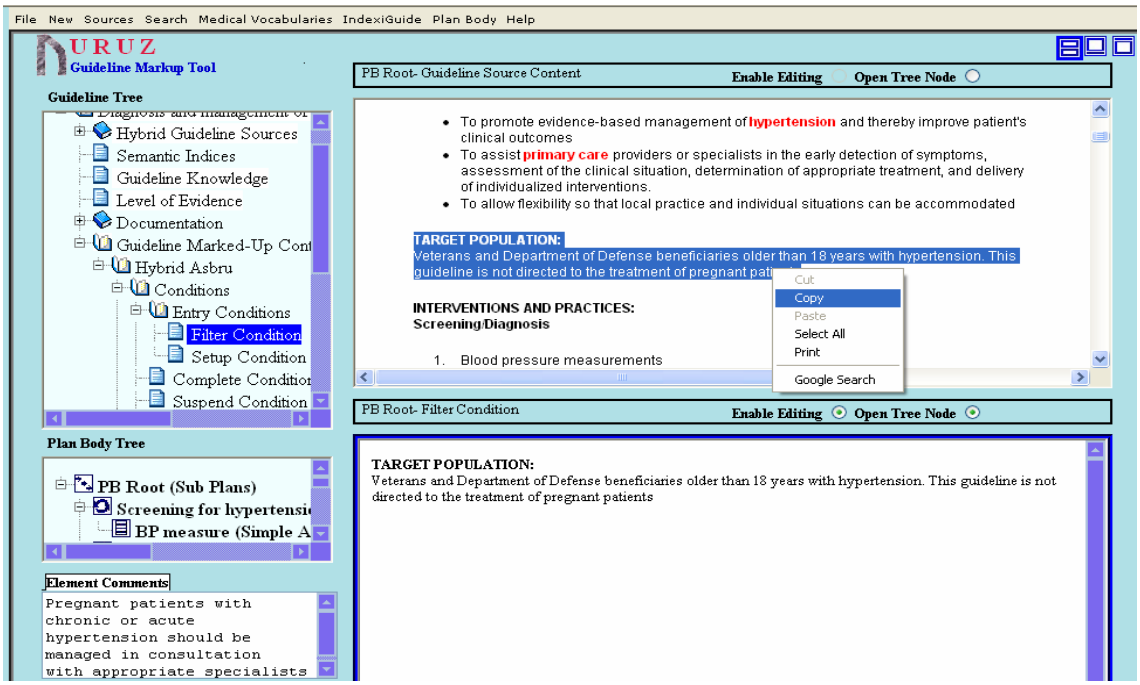

Figure 2. The Uruz guideline-markup tool. The expert physician highlights in one window a portion of a source text, tables or figures, and drags it into a window labeled by a knowledge role (here, the *filter* [eligibility] *condition*) of the target ontology (in this case, Asbru). The text or tables can then be modified. The *Element Comments* knowledge role is used for collaboration.

The medical expert uses the ***IndexiGuide*** tool to *classify* a guideline document along one or more paths in one or more *semantic-axes* indexing trees. Classification is used mostly for retrieval. Examples of semantic axes include *symptoms and signs* (e.g., fever), *diagnostic findings* (e.g., blood pressure), *disorders* (e.g., diabetes), and *treatment* (e.g., chemotherapy).

The **Vaidurya** guideline search engine enables end users to *search* for terms appearing in the free-text guideline source, as well as within a specific knowledge role (e.g., *intentions*) within the target ontology that was used for markup. The user can limit, or *scope* the overall search by indicating one or more concepts within one or more semantic axes.

The **VisiGuide** browsing tool enables editing experts, knowledge engineers, and end users to *browse* a set of guidelines returned by the Vaidurya search engine, as well as *visualize* the structure of each guideline. The user can request returning a selected guideline for further use, such as within the Uruz markup tool, or the IndexiGuide semantic classifier.

The DeGeL authorization model

Due to practical and legal considerations, any digital guideline library must include a comprehensive *authorization* model. The hierarchical model used in DeGeL uses the notions of *virtual expert groups* and of the different *functionalities* inherent in the hybrid meta-ontology model, which imply different levels of authorization. Guideline editors are *members* of one or more (*editing*) *groups* (Figure 3) and have different authorizations in each group.

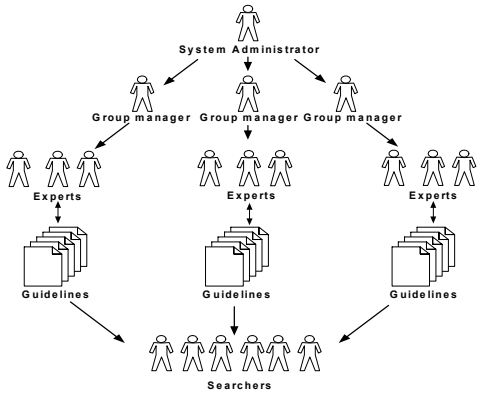

Figure 3. The DeGeL authorization and collaboration model. Guideline editors are members of one or more *groups*. Group members edit guidelines in their group. Most users are *Searchers*, who only browse the library.

Groups are organized by medical specialty (e.g., oncology). Each *group manager* can accept applications to be a group member, and sets and maintains the authorization configuration of each member in that group. Members of a group can only edit and classify guideline documents based on source guidelines *owned* (uploaded) by a group member, but cannot edit guideline documents owned by another group.

The DeGeL authorization model assumes that each module (e.g., Uruz) enables users to perform several *tasks* (Table 1). Each user is given (within each group) a specific authorization configuration for each module. To facilitate management, we have predefined several common authorization profiles (more can be constructed in similar fashion): (1) *Searcher* (visits the library, performs searches, views guidelines which have been edited by other users), (2) *Classifier* (classifies guidelines alongside semantic axes), (3) *Expert Editor* (specifies guidelines' content up to the semi-structured level, using DeGeL's hybrid meta-ontology), (4) *Knowledge Engineer* (cannot markup the guideline, but can fully structure the marked-up text up to machine-comprehensible level in the full target ontology), (5) G*roup manager* (manages permissions of their group members), and (6) *System Administrator* (manages users and groups). Each user profile targets a specific population of potential users. The majority of physicians will use the library as Searchers; a small number of experts in each specialty will serve as Classifiers or Editors.

Module	Relevant Tasks
Vaidurya/ VisiGuide	Search, Retrieve, Visualize, Browse guideline sources or guideline documents
IndexiGuide	View guideline indices, Classify guideline documents
URUZ	View, Edit, Search within guideline documents
Guideline management	Create, Delete guideline sources and documents
Group management	Add, Remove group members; Modify group members details and specific authorizations
Axes builder	View, Modify Semantic classification axes
System administration	Add, Remove groups, module-tasks, user profiles, users

Table 1. Examples of several DeGeL modules and the tasks they enable users to perform.

The default configuration for each authorization profile is predefined (Table 2). A group manager can easily assign a new member to a predefined authorization profile, possibly modifying the configuration if needed, using a Web-based graphical *authorization-management* tool, which we had developed for that purpose. The tool is also used by system administrators to manage all DeGeL users, including group managers. Group managers and administrators can view details of group members, authorize addition of new members, and change authorization configurations for existing members. For example, selecting the *Classifier* authorization profile defines a particular default configuration, which authorizes classification in *IndexiGuide*, but not editing in *Uruz*. (When the tool is being used by a system administrator, it displays additional options for extended maintenance).

The DeGeL collaboration model

There are several means of collaboration among DeGeL editors. (1) The Web-based, distributed expert group model enables several co-editors to work on the same guideline, (e.g., each marking a different knowledge role). (2) Information can be shared among editors, using the *element-comments* editing knowledge role (see Figure 2). (3) A meta-ontology element (i.e., common to all guideline representation formats), called the *clipboard,* enables editors to create a temporary workspace, which supports sharing any type of free text, figures, or tables, from any source document, thus facilitating the editing process. (4) Editors can copy existing marked-up guidelines (edited by their colleagues), give them a new title, modify them, and thus create a new marked-up guideline. (5) Editors can mark-up an existing source (uploaded by a colleague) using a different target ontology than the one used to create an existing guideline document.

Summary and discussion

We have developed a distributed, Web-based architecture (DeGeL) to support all tasks required for guideline-based medical care. DeGeL uses *hybrid*, multiple-ontology and multiple-format representations, which include a combination of free-text, semi-structured text, and a fully structured, machine-comprehensible format.

User-profile	Module	Authorized tasks	Task applies to
Searcher	Vaidurya search engine	*	All guidelines
	Group management	Update details	Own details
Classifier	Vaidurya search engine	*	All guidelines
	IndexiGuide (classification)	*	Group's guidelines
	Group management	View group's public details	Group's members
		update details	Own details
	URUZ markup tool	View Edited Guideline	Group's guidelines
Expert editor	Vaidurya search engine	*	All guidelines
	IndexiGuide (classification	*	Group's guidelines
	URUZ markup tool	*	Group's guidelines
	Guideline management	Create, Modify	Group's guidelines
	Group management	View group's public details	Group's members
		Update details	Own details
Knowledge engineer	Vaidurya search engine	*	All guidelines
	IndexiGuide (classification	View Guideline Classification	Group's guidelines
	URUZ markup tool	View Edited Guideline	Group's guidelines
	Executable language editing	*	Group's guidelines
	Group management	View group's public details	Group's members
		update details	Own details
Group manager	All guideline modules	*	Group's guidelines
System administrator	All modules, including Axes builder and System Administration	*	All guidelines

Table 2. Predefined authorization profiles in DeGeL. Note that only the System Administrator can edit the contents of the semantic classification axes, or of the guideline meta-ontology. * = All tasks in the module..

A hybrid representation caters for the different capabilities of expert physicians and knowledge engineers, and presents a possible solution for the problem of gradual, graceful conversion of large masses of clinical guidelines into an executable format. At the same time, hybrid representations preserve readability and effective search and retrieval of guidelines.

The multiple-user collaboration and authorization model presented here is based on a virtual, distributed medical-specialty *authoring group* notion, and on the different functionalities implied by the hybrid-representation model. The model is inspired by the legal and practical considerations involved in editing medical knowledge. Preliminary assessments of the DeGeL tools, using the Asbru and GEM ontologies, are highly encouraging; formal evaluations are under way.

Acknowledgments

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References

1. Grimshaw, J.M. and Russel, I.T. (1993). Effect of clinical guidelines on medical practice: A systematic review of rigorous evaluations. *Lancet*, 342: 1317–1322.
2. Tu, S.W., Kahn, M.G., Musen, M.A., Ferguson, J.C., Shortliffe, E.H., and Fagan, L.M. (1989). Episodic Skeletal-plan refinement on temporal data. *Communications of ACM* 32: 1439–1455.
3. Musen M. A., Carlson R. W., Fagan L. M., and Deresinski S. C. (1992). T-HELPER: Automated Support for Community-Based Clinical Research. *Proceedings of the Sixteenth Annual Symposium on Computer Applications in Medical Care*, Washington, D.C., 719-723.
4. .Herbert, S.I., Gordon, C.J., Jackson-Smale, A., and Renaud Salis, J-L. (1995). Protocols for clinical care. *Computer Methods and Programs in Biomedicine* 48: 21–26.
5. Musen, M.A., Tu, S.W., Das, A.K., and Shahar, Y. (1996). EON: A component-based approach to automation of protocol-directed therapy. *Journal of the American Medical Information Association* 3(6): 367–388.
6. Shahar, Y., Miksch, S., and Johnson, P. (1998). The Asgaard project: A task-specific framework for the application and critiquing of time-oriented clinical guidelines. *Artificial Intelligence in Medicine* (14): 29-51.
7. Fox, J., Johns, N., and Rahmanzadeh, A. (1998). Disseminating medical Knowledge: the PROforma approach. *Artificial Intelligence in Medicine*, 14: 157-181.
8. Peleg M, Boxwala A. A., Omolola O., Zeng Q., Tu, S.W, Lacson R., Bernstam, E., Ash, N., Mork, P., Ohno-Machado, L., Shortliffe, E.H., and Greenes, R.A. (2000). GLIF3: The Evolution of a Guideline Representation Format In Overhage M.J., ed., *Proceedings of the 2000 AMIA Annual Symposium* (Los Angeles, CA, 2000), Hanley & Belfus, Philadelphia.
9. Johnson PD, Tu SW, Booth N, Sugden B, and Purves IN (2000). Using scenarios in chronic disease management guidelines for primary care. In Overhage M.J., Ed., *Proceedings of the 2000 AMIA Annual Symposium* (Los Angeles, CA, 2000), Hanley & Belfus, Philadelphia.
10. Tang PC and Young CY (2000). ActiveGuidelines: Integrating Web-Based Guidelines with Computer-Based Patient Records. In Overhage M.J., Ed., *Proceedings of the 2000 AMIA Annual Symposium* (Los Angeles, CA, 2000), Hanley & Belfus, Philadelphia.
11. Shiffman RN, Karras BT, Agrawal A, Chen R, Marenco L, Nath S. (2000). GEM: a proposal for a more comprehensive guideline document model using XML. *Journal of the American Medical Informatics Association* 7(5): 488-498.
12. Shahar Y, Young O., Shalom E., Mayaffit A., Moskovitch R., Hessing A., and Galperin M. DEGEL: A hybrid, multiple-ontology framework for specification and retrieval of clinical guidelines. *Proceedings of the 9th Conference on Artificial Intelligence in Medicine-Europe* (*AIME*) '03, Protaras, Cyprus.
13. Advani, A., Musen, M.A., and Shahar, Y. (2001). Medical quality assessment by scoring adherence to guideline intentions. *Proceedings of the 2001 AMIA Annual Fall Symposium*, Washington, DC.